MULTI-COLOR ELECTROPHORETIC DISPLAYS AND MATERIALS FOR MAKING THE SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application is a continuation-in-part of U.S. Ser. No. 08/504,896, filed Jul. 20, 1995, and is a continuation-in-part of U.S. Ser. No. 08/983,404, filed Jul. 19, 1997, and is a continuation-in-part of U.S. Ser. No. 08/935,800, filed Sep. 23, 1997, the entire disclosures of which are hereby incorporated by reference herein. The present application also claims priority to U.S. Ser. No. 08/504,896, filed Jul. 20, 1995, U.S. Ser. No. 08/983,404, filed Jul. 19, 1997 and now abandoned, U.S. Ser. No. 08/935,800, filed Sep. 23, 1997, U.S. Ser. No. 60/057,133, filed Aug. 28, 1997, U.S. Ser. No. 60/057,716, filed Aug. 28, 1997, U.S. Ser. No. 60/057,799, filed Aug. 28, 1997, U.S. Ser. No. 60/057,163, filed Aug. 28, 1997, U.S. Ser. No. 60/057,122, filed Aug. 28, 1997, U.S. Ser. No. 60/057,798, filed Aug. 28, 1997, U.S. Ser. No. 60/057,118, filed Aug. 28, 1997, U.S. Ser. No. 60/059,543, filed Sep. 19, 1997, U.S. Ser. No. 60/059,358, filed Sep. 19, 1997, U.S. Ser. No. 60/065,630, filed Nov. 18, 1997, U.S. Ser. No. 60/065,605, filed Nov. 18, 1997, U.S. Ser. No. 60/065,529, filed Nov. 18, 1997, U.S. Ser. No. 60/066,147, filed Nov. 19, 1997, U.S. Ser. No. 60/066,245, filed Nov. 20, 1997, U.S. Ser. No. 60/066,246, filed Nov. 20, 1997, U.S. Ser. No. 60/066,115, filed Nov. 21, 1997, U.S. Ser. No. 60/066,334, filed Nov. 21, 1997, U.S. Ser. No. 60/066,418, filed Nov. 24, 1997, U.S. Ser. No. 60/071,371, filed Jan. 15, 1998, U.S. Ser. No. 60/070,940, filed Jan. 9, 1998, U.S. Ser. No. 60/072,390, filed Jan. 9, 1998, U.S. Ser. No. 60/070,939, filed Jan. 9, 1998, U.S. Ser. No. 60/070,935, filed Jan. 9, 1998, U.S. Ser. No. 60/074,454, filed Feb. 12, 1998, U.S. Ser. No. 60/076,955, filed Mar. 5, 1998, U.S. Ser. No. 60/076,959, filed Mar. 5, 1998, U.S. Ser. No. 60/076,957, filed Mar. 5, 1998, U.S. Ser. No. 60/076,956, filed Mar. 5, 1998, U.S. Ser. No. 60/076,978, filed Mar. 5, 1998, U.S. Ser. No. 60/078,363, filed Mar. 18, 1998, U.S. Ser. No. 60/081,374, filed Apr. 10, 1998, U.S. Ser. No. 60/081,362, filed Apr. 10, 1998, U.S. Ser. No. 60/083,252, filed Apr. 27, 1998, U.S. Ser. No. 60/085,096, filed May 12, 1998, U.S. Ser. No. 60/090,223, filed Jun. 22, 1998, U.S. Ser. No. 60/090,222, filed Jun. 22, 1998, U.S. Ser. No. 60/090,232, filed Jun. 22, 1998, U.S. Ser. No. 60/092,046, filed Jul. 8, 1998, U.S. Ser. No. 60/092,050, filed Jul. 8, 1998, U.S. Ser. No. 60/092,742, filed Jul. 14, 1998, and U.S. Ser. No. 60/093,689, filed Jul. 22, 1998, the entire disclosures of which are hereby incorporated by reference herein.

FIELD OF THE INVENTION

The present invention relates to electrophoretic displays, particularly encapsulated electrophoretic displays, and to materials useful in fabricating such displays.

BACKGROUND OF THE INVENTION

Electrophoretic displays have been the subject of intense research and development for a number of years. Electrophoretic displays have attributes of good brightness and contrast, wide viewing angles, state bistability, and low power consumption when compared with liquid crystal displays. Nevertheless, problems with the long-term image quality of these displays has, to date, prevented their widespread usage.

The recent invention of encapsulated electrophoretic displays solves many of these problems and offers additional

advantages compared to liquid crystal displays. Some added advantages are the ability to print or coat the display material on a wide variety of flexible and rigid substrates. The clustering and settling problems, which plagued prior art electrophoretic displays and resulted in inadequate lifetimes for the displays are now overcome.

The purpose of this disclosure is to describe electrophoretic displays, especially encapsulated electrophoretic displays, and classes of materials, as well as some specific materials, which should be useful in their construction.

SUMMARY OF THE INVENTION

The successful construction of an encapsulated electrophoretic display requires the proper interaction of several different types of materials and processes. Materials such as a polymeric binder, a capsule membrane, and the electrophoretic particles and fluid must all be chemically compatible. The capsule membranes may engage in useful surface interactions with the electrophoretic particles, or may act as an inert physical boundary between the fluid and the binder. Polymer binders may set as adhesives between capsule membranes and electrode surfaces.

In some cases, a separate encapsulation step of the process is not necessary. The electrophoretic fluid may be directly dispersed or emulsified into the binder (or a precursor to the binder material) to form what may be called a "polymer-dispersed electrophoretic display". In such displays, the individual electrophoretic phases may be referred to as capsules or microcapsules even though no capsule membrane is present. Such polymer-dispersed electrophoretic displays are considered to be subsets of encapsulated electrophoretic displays.

In an encapsulated electrophoretic display, the binder material surrounds the capsules and separates the two bounding electrodes. This binder material must be compatible with the capsule and bounding electrodes and must possess properties that allow for facile printing or coating. It may also possess barrier properties for water, oxygen, ultraviolet light, the electrophoretic fluid, or other materials. Further, it may contain surfactants and cross-linking agents, which could aid in coating or durability. The polymer-dispersed electrophoretic display may be of the emulsion or phase separation type.

The present invention provides electrophoretic displays, particularly encapsulated electrophoretic displays, and materials for use in such displays. The capsules may be spherical or non-spherical in shape. In electrophoretic displays, at least some of the particles are moved or rotated by application of electric fields. The electric field may be an alternating-current field or a direct-current field. The electric field may be created by at least one pair of electrodes disposed adjacent a binder material containing the particles. The particles may be absorbing pigments, scattering pigments or luminescent particles, for example. The particles may be made up of some combination of dye, pigment, polymer.

Such displays may also include, for example, one type of particle that retroreflects, or substantially retroreflects, light and another type that absorbs light. Application of an electric field may cause the particles in an encapsulated display to orient so that the capsule retroreflects, or substantially retroreflects, light. Application of another electric field may cause the particles to orient so that the capsule absorbs, or does not retroreflect, light. A display may also include a reflective substrate, so that orientation of one type of particle in a particular pattern causes light to pass through the